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Soft Recovery of the M855 Bullet

by Robert M. Keppinger and James M. Garner

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14. ABSTRACT

A research effort to characterize the flight characteristics at range of the M855 North Atlantic Treaty Organization (NATO) ball ammunition was conducted by the U.S. Army Research Laboratory, Flight Sciences Branch. This development effort required a soft recovery method. A two phase test approach to recover M855 projectiles with little to no damage was undertaken. Both phases utilized gelatin blocks as the catch medium for the projectile. Bullet catchers currently on the market for forensic science often impart some damage to the projectile. This level of damage was considered too great for the current study. Long range calculations show that the velocity of the bullet slows down faster than the bullet's spin rate decays. The flow angle across the bullet changes accordingly and creates the bullet's characteristic behavior. Recovery of the projectile to verify engraving angles is therefore, necessary. This report discusses catching M855 projectiles at energy equivalent states by varying impact range and velocity.

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5.56 mm, recovery, interior ballistics

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1. Introduction

A traditional method for determining the aerodynamic characteristics of bullets involves the spark range. Bullets are typically fired through the surveyed range, and spark shadowgraph photographs of the bullet's orientation throughout the flight are used to determine the bullets displacement and angular orientation history at a number of predetermined stations within the range. From the measured motion, the aerodynamic characteristics of the bullet can be deduced.

Spark ranges are typically limited in length, and therefore, can only capture a segment of the complete trajectory. To obtain the aerodynamic characteristics for the complete range of velocities along the trajectory, bullets are fired using systematically reduced charges to obtain a range of velocities below the typical reference muzzle velocity of the round. This approach generally works well for a variety of projectiles. However, for projectiles fired from rifled barrels, it is unknown as to whether the engraving on the bullet significantly effects the aerodynamics. Near the muzzle, the grooves engraved on the bullet surface are aligned with the flow of air near the body surface. This is shown in figure 1. As the projectile flies further downrange, the bullet's forward velocity slows down faster than the bullet's spin rate decays, and the flow is no longer aligned with the grooves from the engraving. When this occurs, the bullet is said to be "over-spun".

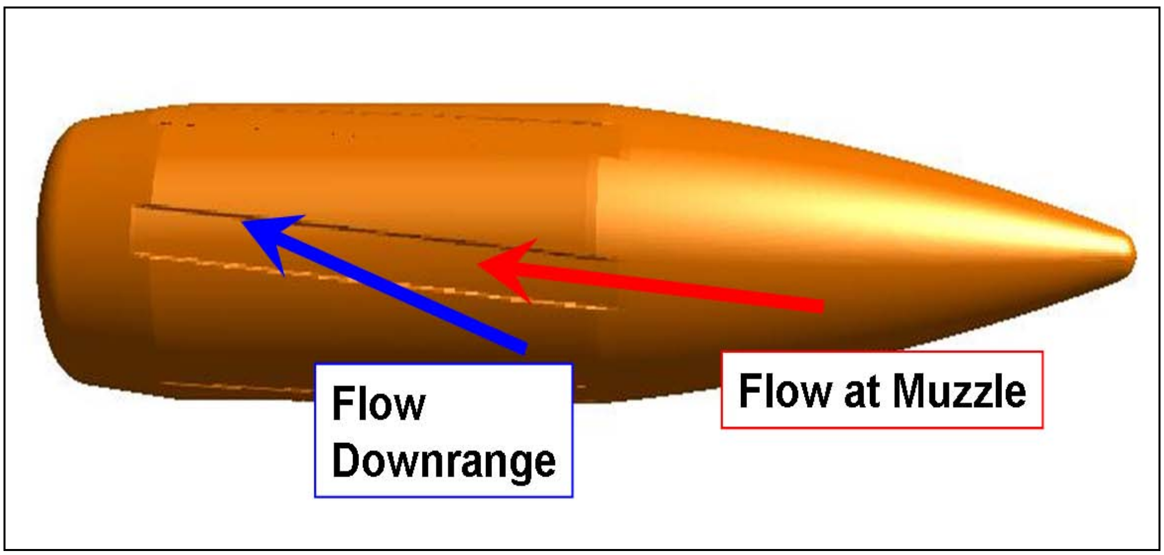

Figure 1. M855 with rifling.

Over-spun projectiles cause problems for aerodynamic testing when the bullets are downloaded and fired from the standard rifle. With the reduced velocity of the projectile, the spin rate at the muzzle is typically much lower than the spin rate at the same velocity for a bullet fired using a standard charge. The matched spin rate (the spin rate/velocity ratio that has the flow following the angle of the grooves on the projectile) for the downloaded bullet can be obtained by firing a gun with a different twist rate. However, even though the bullet now has the correct spin rate, the engraving pattern on the bullet is now changed with potential side effects on the aerodynamics.

One method to ensure that the bullet has a matched spin rate at the reduced velocities, while maintaining the proper engraving pattern on the bullet, is to fire from a rifle with the standard twist rate and recover the bullets. After recovery, the bullets can be saboted and re-launched from the larger bore gun with the desired twist rate. To achieve this, bullets are initially fired into a soft recovery media so the bullet is not damaged on impact.

Typically, recovery with no bullet damage requires that the target be placed far downrange so the velocity is substantially reduced by aerodynamic drag. Depending on the size of the target, a large number of bullets may have to be fired (as some inevitably miss) to obtain a sufficient quantity of recovered bullets.

Another approach to recover bullets is to fire them at a reduced propellant charge. This significantly reduces the logistical burden on recovery because a much shorter range can be used to produce velocities low enough to ensure that the bullet is minimally damaged on impact. Correspondingly fewer bullets and shots are required to hit the target, since the range is decreased. However, since there is some deformation of the bullet in-bore, it is not clear whether the bullets fired at reduced charges have precisely the same engraving patterns, physical characteristics, or shape as the bullets fired at full change.

This report discusses these two approaches for bullet recovery. Measured physical characteristics of the bullets were recorded for both pre and post firings. The engraved lands on the recovered bullet are measured for length and width. An evaluation of the data can determine which means of recovery is appropriate for selected testing.

2. Test Set-up

Two phases of this study were performed to determine the benefits of each type of recovery. The first phase was fired at M-Range located at Aberdeen Proving Ground, MD. M-Range is an outdoor facility used for accuracy and human studies testing. The test phase called for the M855 to be fired at the standard velocity (propelling charge). The bullet was fired into 20% (by weight) gelatin blocks located 600 m down range. A 20% gelatin block is made from 8-lb Knox brand gelatin powder and 32 lbs of water. There were nine gelatin blocks, each block measuring

0.2 × 0.2 × 0.46 m. The blocks were stacked three high and three across representing a target size of 24 in × 0.61 m. With this set-up, 40 M855 rounds were fired and only 5 rounds were recovered. This was likely due to three factors: the ammunition dispersion of the M855 round at 600 m, the cross winds causing the bullets to drift outside of the target area, and the aim error of the M855 when fired from a M16A2 rifle from the shoulder firing position.

The second phase of testing was conducted at the Aerodynamics Experimental Facility, also located at Aberdeen Proving Ground, MD. The facility is, as the name suggests, the U.S. Army Research Laboratory's (ARLs) location to acquire small caliber aerodynamics through live-fire testing, and is managed and maintained by the Flight Sciences branch of the ARL. The present testing was conducted in a side tunnel portion of the range and did not require the full instrumentation suite typically used to obtain aerodynamics. This phase called for the cartridges to be downloaded and fired into a 20% gelatin block at a range of 3.04 m. The downloading of the propellant simulated the downrange bullet velocity. Catching the bullet at this velocity results in a much lower striking force on the bullet and hence less damage. The weapon was hard mounted in a Frankford Arsenal rest. The weapon was aimed on the center of the block using a bore sight. Better accuracy over the shorter range enabled the overall target configuration to be reduced to one gelatin block measuring 0.2 × 0.2 × 0.61 m.

3. Bullet Recovery

To bring the bullet to a stop within the gel block, the kinetic energy is deposited in the target through the work done by the resistive force of the target on the bullet. The gel block resistance force applied over the stopping distance (opposing the kinetic energy) arises from penetration of the gel and results in the deceleration of the bullet. This resistance force is not uniform over the impact, penetration and eventual stoppage of the projectile. Determining the resistance force as a function of time experimentally, while useful, would require more extensive instrumentation. In the context of the current experiment, the impact kinetic energy combined with the observed experimental results yield useful metrics that indicate whether the target dimensions are suitable for stopping the bullet within the target, and whether the impact energies are small enough to prevent bullet damage in the target.

The propellant charge weight of a standard M855 ball round is 1.76 g with an average muzzle velocity of nominally 940 m/s. The estimated velocity at 600 m of an M855 fired at full charge is 346.8 m/s with a kinetic energy of nominally 240 Joules. The range of 600 m for damage free recovery in phase 1 was selected based on prior experience of the author. Some data obtained from phase 1 testing was applied to the downloaded phase. An equivalent experimental charge weight and striking velocity were determined. From these data points the resistance energy required to catch the bullet for each shot, was calculated and is shown in table 1.

Table 1. First phase 2 test.

Round No.	Round Type	Down-Loaded Charge Weight (g)	Velocity (m/s)	Required Resistance Energy (J)
1	M855	0.52	420.2	360.1
2	M855	0.26	0	0
3	M855	0.39	314.8	202.1
4	T/N	0.39	299.2	182.6
5	T/N	0.39	289.8	171.4
6	T/N	0.32	0	0
7	T/N	0.37	241.9	170.5

The minimal charge weight required to launch an M855 from an M16A2 rifle was also determined. Two failures occurred, as rounds 2 and 6 stuck in the bore and these propellant charges formed a lower limit for downloading.

After reviewing the data obtained from the downloaded test, an additional test seeking more interior ballistics data was completed. For this test all cartridges were loaded with 0.387 g of WC844 powder and a standard M855 projectile with an average mass of 4.017 g. The results of this test are in table 2.

Table 2. Second phase 2 test.

Round No.	Barrel ID	Velocity (m/s)	Energy Joules
25836	old 5	367.27	271.014
25837	old 5	364.83	267.428
25838	old 5	393.17	310.597
25839	old 5	358.12	257.688
25840	old 5	351.42	248.129
25841	old 5	378.85	288.377
25842	old 5	396.83	316.403
25843	old 5	372.75	279.172
25844	old 5	371.53	277.348
25845	old 5	380.37	290.702
25846	old 5	387.69	301.99
25847	old 5	385.86	299.148
25848	old 5	391.65	308.194
25849	old 5	383.42	295.379
25850	old 5	359.95	260.326

4. Physical Measurements

The use of physical measurements is essential in determining if the bullets sustained any significant damage due to impact with the gelatin blocks. In phase 1, bullets were fired at the standard velocity. These phase 1 bullets were fired without taking any a-priori physical measurements. In order to establish a comparison baseline for these rounds, physical measurements from an earlier M855 test were used. Table 3 contains the baseline measurements for the M855, while table 4 displays actual measurements of the recovered bullets.

Table 3. Base line M855.

Nomenclature	**NATO* M855 Ball**				
Projectile Number	**1**	**2**	**3**	**4**	**5**
Projectile Length (mm)	23.08	23.16	23.17	23.11	23.11
Reference Diameter 1 (mm)	5.68	5.68	5.69	5.66	5.64
Ref Diameter Location From Base (mm)	3.74	3.85	3.45	3.46	3.46
Projectile Mass (g)	4.01	4.04	4.05	4.05	4.04
CG from Base (mm)	8.54	8.71	8.62	8.78	8.64
Axial Moment of Inertia (g-cm^2)	0.14124	0.14167	0.14267	0.14186	0.14147
Transverse Moment of Inertia (g-cm^2)	1.12984	1.1417	1.13884	1.14403	1.14307

* North Atlantic Treaty Organization (NATO)

Table 4. Recovered 600 m.

Projectile Number	**1**	**2**	**3**	**4**	**5**
Projectile ID	—	—	—	—	—
Projectile Length (mm)	23.17	23.02	23.11	23.10	23.28
Reference Diameter 1 (mm)	5.69	5.69	5.63	5.64	5.69
Ref Diameter Location From Base (mm)	3.13	2.75	3.14	3.11	3.21
Projectile Mass (g)	4.01	4.05	4	4.04	4.06
CG from Base (mm)	8.66	8.46	8.57	8.83	8.61
Axial Moment of Inertia (g-cm^2)	0.13821	0.13829	0.1374	0.13744	0.14023
Transverse Moment of Inertia (g-cm^2)	1.16894	1.1784	1.15432	1.14804	1.16306

In the downloaded phase, projectiles received pre-and post- firing physical measurements. Tables 5 and 6, show the physical measurement data taken for pristine bullets (bullets that have not already been loaded or fired). Reloading of bullets occurs when propellant charges are modified. The choice of pristine bullets eliminates sources of error that might arise from prior loading procedures on the bullet. This ensures that no prior crimping effects influence the bullet integrity or weight. During this test it was decided to fire bullets that used a core composed of

Tungsten/Nylon (T/N). This was done to further evaluate the elastic capabilities of a new bullet core design.

Table 5. Pre-firing, down-loaded rounds.

Projectile Number	**1**	**3**	**4**	**5**	**7**
Projectile ID	**M855**	**M855**	**T/N**	**T/N**	**T/N**
Projectile Length (mm)	23.05	23.00	22.95	23.29	23.40
Reference Diameter 1 (mm)	5.66	5.69	5.69	5.66	5.69
Ref Diameter Location From Base (mm)	3.69	3.67	3.12	3.12	3.55
Projectile Mass (g)	4.03	4.03	4.04	4.04	4.04
CG from Base (mm)	8.62	8.80	8.76	9.07	8.67
Axial Moment of Inertia (g-cm^2)	0.14182	0.14128	0.1422	0.14186	0.14147
Transverse Moment of Inertia (g-cm^2)	1.14265	1.13492	1.15099	1.17402	1.16864

Table 6. Recovered down-loaded rounds.

Projectile Number	**1**	**3**	**4**	**5**	**7**
Projectile ID	**M855**	**M855**	**T/N**	**T/N**	**T/N**
Projectile Length (mm)	23.17	23.02	23.11	23.10	23.28
Reference Diameter 1 (mm)	5.70	5.68	5.63	5.64	5.68
Ref Diameter Location From Base (mm)	3.13	2.75	3.14	3.11	3.21
Projectile Mass (g)	4.01	4.05	4	4.04	4.06
CG from Base (mm)	8.65	8.46	8.57	8.83	8.61
Axial Moment of Inertia (g-cm^2)	0.13821	0.13829	0.1374	0.13744	0.14023
Transverse Moment of Inertia (g-cm^2)	1.16894	1.1784	1.15432	1.14804	1.16306

5. Recovered M855s

Digital photographs display the grooves engraved into the bullet. The bullet material yields to fill the bore and prevent blow-by. Some of the deformed material is constricted and is forced against the lands at a great pressure. This is what leaves the wear marks in between the grooves. In a bullet with a pronounced cocking angle these marks would be more pronounced on a particular side. Reference figures 2 and 3.

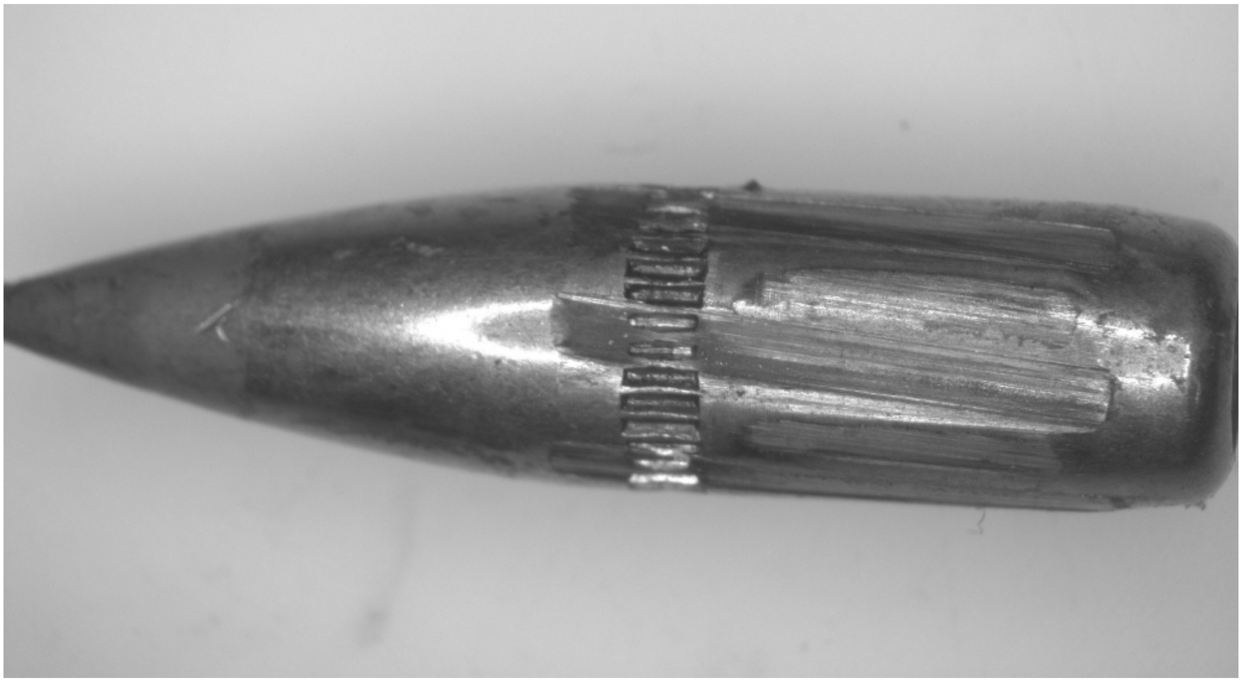

Figure 2. Phase 1 recovered M855 (600 m).

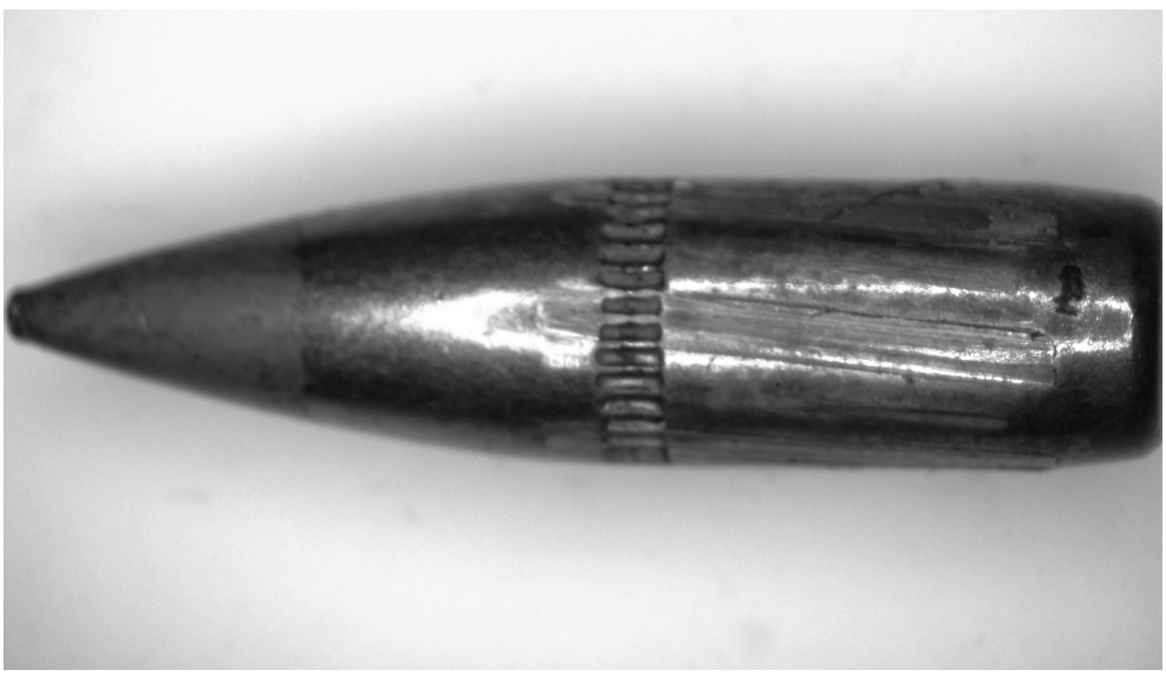

Figure 3. Phase 2 recovered down-loaded M855.

The engravings of the recovered bullets were measured using an optical comparator. Both the length and the width were measured and the results are shown in tables 7 and 8 below.

Table 7. Measurement of down-loaded projectiles.

Engraving Length (mm)	Engraving Width (mm)
10.00	1.04
10.26	1.09

Table 8. Measurement of recovered projectile 600 m.

Engraving Length (mm)	Engraving Width (mm)
10.19	1.04
10.24	1.04
10.64	1.09
10.41	1.09
10.41	1.09

6. Conclusions

While there were only small samples of bullets for testing between both phases, the findings were valuable. Comparison of the photographs between both phases and the measurements taken of the lands, an average measurement, revealed the length is within 0.229 mm and the width matches. Since the engravings are essentially geometrically consistent, the bullet is not abnormally deforming, under a standard or reduced velocity launch. The launch velocity of a bullet appears to have little or no impact on how deep the bullet engravings are, provided the threshold for bore exit is reached (charges > 5g). The only other factors that could influence the depth of the engravings would be damage to the lands or variability of the diameter of the bullet and the inconsistency of the bore diameters in the rifled barrel. A side benefit for future firing is the determination of the exit threshold propelling charge.

The technique of firing at a reduced charge into carefully tailored soft catch media is probably a preferred option in many cases. This is especially appropriate for tests with small numbers of test ammunition or if access to outdoor long range test facilities is restricted or nonexistent. The experimental data and the technique of bullet recovery discussed in this report has been shared with and implemented by the Ordnance and Materials Branch of ARL and Arrow Tech Associates, Inc.

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